EFFECT OF L-ASCORBIC ACID AS ADDITIVE FOR EXHAUST EMISSION REDUCTION IN A DIRECT INJECTION DIESEL ENGINE USING MANGO SEED METHYL ESTER

by

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In this present study the effect of L-ascorbic acid antioxidants additive for oxides of nitrogen emission reduction in a neat mango seed biodiesel fueled direct injection Diesel engine. The antioxidant additive L-ascorbic acid is tested on a Kirloskar-make four stroke water cooled single cylinder Diesel engine of 5.2 kW. There are four proportions of additive are used: 1 ml, 2 ml, 3 ml, and 4 ml. Among the different additive proportion, 4 ml concentration of L-ascorbic acid additive is optimal as oxides of nitrogen levels are substantially reduced upto 9% in the whole load range in comparison with neat biodiesel. However, hydrocarbon and carbonmonoxide emissions are found to have slightly increased by the addition of additive with biodiesel.

Key words: *L-ascorbic acid, mango seed oil, biodiesel, emission, oxides of nitrogen reduction, neat biodiesel*

Introduction

The demand for energy around the world is increasing, specifically the demand for petroleum fuels. World energy consumption is expected to increase to 180,000 GWh per year by 2020 [1]. Overutilization of petroleum fuels and the increasingly stringent emission regulations, biofuels, such as ethanol and biodiesel, have been explored to reduce fossil fuel consumption and engine emissions. Biodiesel is an alternative diesel fuel consisting of alkyl monoesters of fatty acids derived from vegetable oil or animal fats. Because of its renewable, non-toxic and sulfur-free more research has focused on the use of biodiesel on Diesel engines [2, 3]. Physical properties of the biodiesel is much closer to that of the Diesel, most studies reports that there is slighter power loss while using biodiesel as a fuel in a Diesel engine due to the lower calorific value of the biodiesel [4-6]. Most researches reports that the use of biodiesel will results in better emission characteristics except NO_x emission [7-13].

The NO_x emission formed inside the combustion due to the presence of excess oxygen and temperature, at elevated temperature molecular nitrogen will dissociate to form atomic nitrogen and forms NO_x emission [14-16]. Use of additives and emulsified fuel will have positive effect on reducing the NO_x emission from biodiesel fueled engine [17].

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In this work mango seed oil is selected to prepare biodiesel. Mango seeds are collected from the mango juice extraction and processing center in Tamilnadu state of India. The company processes more than 50,000 tonnes of mangoes to extract juice and produces about 5,000 tonnes of organic waste which are mostly wasted as landfill. Utilization of the waste mango seed by producing biodiesel and using it in the diesel power plant will reduce the dependency on fossil fuel.

Mango seed oil contain about 42% of mono unsaturated fatty acid and 14% poly unsaturated fatty acid [18]. Due to the presence of higher amount of unsaturated fatty acid will results in the reduction in stability of the fuel which will increases the emission characteristics.

In this study effect of L-ascorbic acid (LAA), an antioxidant on the emission characteristics and performance characteristics of the mango seed biodiesel are investigated and it is compared with the diesel fuel. Four different quantities of the additives (1 ml, 2 ml, 3 ml, and 4 ml) is added with the neat mango seed oil biodiesel.

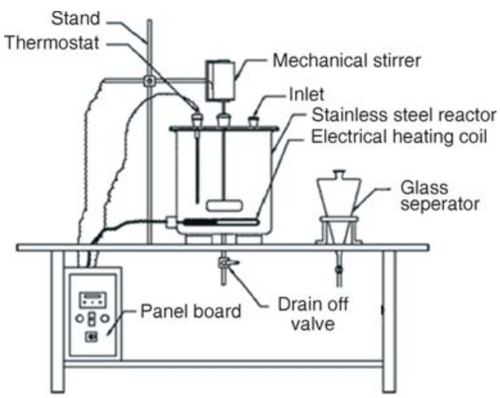

Figure 1. Schematic diagram of biodiesel plant (5 litre capacity)

Materials and methods

Fuel preparation

A laboratory-scale biodiesel production set-up is as shown the fig. 1. It consists of a motorized stirrer, straight coil electric heater and stainless steel containers. The system was designed to produce maximum five liter of biodiesel. Temperature of the mixture of the triglyceride, methanol, and catalyst were maintained at about 60 °C. Transesterification is done using methanol (CH_3OH) in the presence of potassium hydroxide as catalyst.

Fuel properties

Table 1. Properties of test fuel

Properties	Diesel	MSME	MSME + 1 ml LAA
Density at 15 °C [gmcm^{-3}]	0.8344	0.8835	0.8840
Kinematic viscosity at 40 °C [mm^{2}s^{-1}]	3.07	6.32	6.32
Flash point [°C]	60	150	151
Fire point [°C]	69	161	159
Cloud point [°C]	15	27	26
Calorific value [kJkg^{-1}]	44125	39292	39298
Cetane number	48	52	52

A series of tests were performed to characterize the compositions and properties of the mango seed methyl ester (MSME). The fuel properties of diesel, MSME an MSME with 1 ml of LAA additive are shown in tab. 1. It is shown that the viscosity of biodiesel is evidently higher than that of diesel fuel. The density of the biodiesel is approximately 6.02% higher than that of diesel fuel. The lower heating value is approximately 9.08% lower than that of diesel fuel. Therefore, it is necessary to increase the fuel amount to be injected into the combustion chamber to produce same amount of power. Fuels with flash point above 52 °C are regarded as safe. Thus, biodiesel is an extremely safe fuel to handle compared to that of diesel fuel.

Experimental procedure

An experimental set-up was configured with necessary instruments to evaluate the emission and performance parameters of the compression ignition engine at different operating conditions. Single cylinder water-cooled four-stroke direct injection Diesel engine Kirloskar TV-I, injection timing 220 kg/cm^2, compression ratio of 17.5:1, developing 5.2 kW at 1500 rpm was used for this present work.

Details of the engine are given in tab. 2. The engine coupled to an eddy current dynamometer for load measurement. Fuel flow rate is obtained on the gravimetric basis and the airflow rate is obtained on the volumetric basis. The AVL 437 smoke meter is used to measure the smoke density, and AVL 444 di-gas analyser is used to measure the CO, HC, and NO_x emission from the engine. A burette is used to measure the fuel consumption for a specified time interval. The experimental set-up is indicated in fig. 2.

The engine was allowed to run with sole fuel at various loads for nearly ten minutes to attain the steady-state and constant speed conditions. The water flow was maintained at constant throughout the experiment. The load, speed and temperature indicators were switched on. The engine was started by cranking after ensuring that there is no load. The engine was allowed to run at the rated speed of 1500 rpm for a period of twenty minutes to reach the steady-state. The fuel consumption was measured by a stop watch. Smoke readings were measured using the Hartridge smoke meter at the exhaust outlet. The amount of NO_x was measured using exhaust gas analyser. The exhaust temperature was measured by using a sensor. Then the load was applied by adjusting the knob, which was connected to the eddy current dynamometer. Experiments were conducted using sole fuel, neat MSME and different proportions of LAA additive with MSME.

Table 2. Specifications of the test engine

Make	Kirloskar TV-1 engine
Type	Single cylinder vertical water cooled 4 stroke diesel engine
Bore × stroke	87.5 mm × 110 mm
Compression ratio	17.5:1
Fuel	Diesel engine
Rated brake power	5.2 kW (7HP)
Speed	1500 rpm
Ignition system	Compression ignition
Ignition timing	23 °bTDC (rated)
Injection pressure	220 bar
Loading device	Eddy current dynamometer
Orifice dia	0.02 m
Dynamometer arm length	0.195 m

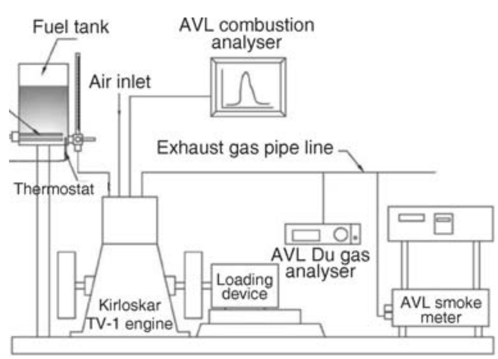

Figure 2. Engine test rig

Results and discussions

Performance characteristics

Specific fuel consumption

Figure 3 shows that variation of specific fuel consumption (SFC) with brake power for Neat diesel, neat MSME, and different proportions of LAA with MSME. The SFC decreases with the increase in load for the test fuels. MSME has higher SFC compared with diesel due to

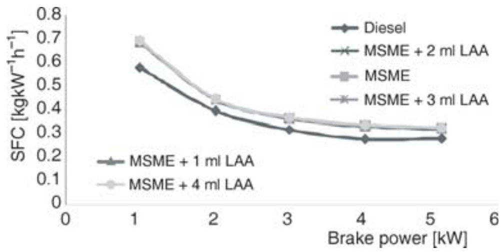

Figure 3. Variation of SFC with brake power

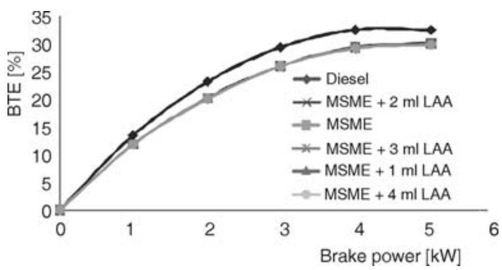

Figure 4. Variation of BTE with brake power

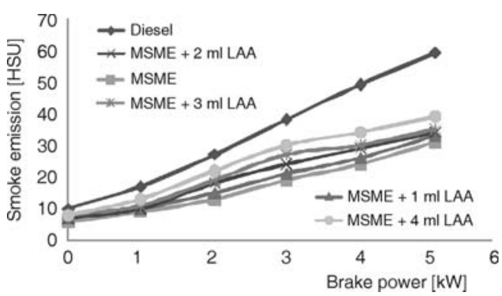

Figure 5. Variation of smoke emission with brake power

the lower calorific value of the MSME. The energy loss due to the variation in calorific value of the MSME is compensated by injecting more fuel into the combustion chamber to produce the same power output, which would result in a substantial increase in SFC of MSME. Addition of LAA does not have any significant effect on the SFC of the engine.

Brake thermal efficiency

Figure 4 shows variation of brake thermal efficiency (BTE) with brake power for Neat diesel, neat MSME and MSME with different proportions of LAA additive. The MSME has lower BTE comparing to diesel. The lower BTE of MSME is attributed to lower heating value and higher viscosity. The average BTE for diesel, MSME, MSME + 1 ml LAA, MSME + 2 ml LAA, MSME + 3 ml LAA, and MSME + 4 ml LAA are 19.718%, 19.598%, 19.580%, 19.554%, 19.536%, 19.499%, respectively.

Emission characteristics

Smoke density

Smoke opacity indicates the soot content on the exhaust gas, it is also a component of particulate matter. The variation of smoke emission with brake power is shown in fig. 5. Smoke emission for all the fuel increases with the increase in the load, because at higher load more fuel is injected in to the combustion chamber and results in availability of fuel rich zones which favours the formation of soot. Smoke emission of MSME is lower than diesel due to the better combustion of biodiesel, owing to the oxygen content of the biodiesel. Addition of LAA additive increases the smoke emission of the MSME but it is still lower than that of diesel. The average value of smoke opacity for diesel, MSME, MSME + 1 ml LAA, MSME + 2 ml LAA, MSME + 3 ml LAA, and MSME + 4 ml LAA are 33, 17.3, 18.6, 20.3, 21.7, 24.3 HSU, respectively.

Oxides of nitrogen

Higher combustion chamber temperature, longer combustion duration, increase in oxygen concentration are the major and fuel borne nitrogen are the major factors for NO_x formation. Figure 6 shows the variation of NO_x with brake power for Neat diesel, neat MSME, MSME with different concentrations. The NO_x emission increases with the increase in load due to the increase in combustion chamber temperature with engine load, which favours the thermal NO_x

formation. Biodiesel being an oxygenated fuel with high cetane number will have a reduced ignition delay, will results in increased resident time of the combustion product inside the combustion chamber will results in increase in NO_x emission. The NO_x emissionis reduced by addition of LAA with MSME due to the reduction in formation of free radicals. The emission characteristics of 4 ml LAA is almost similar to that of the diesel fuel. Addition of more than 4 ml of additive does not have any significant effect on the NO_x emission characteristics.

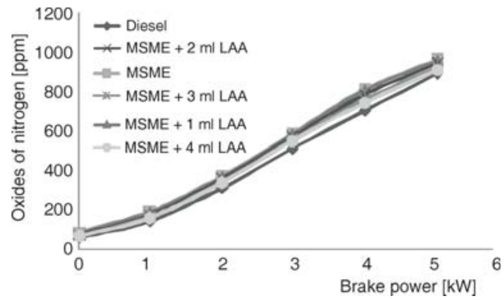

Figure 6. Variation of NO_x with brake power

Carbon monoxide

Low flame temperature and too rich air-fuel ratio are the major causes of CO emissions. Figure 7 shows the variation of CO with brake power for diesel, neat MSME and different blends of MSME with LAA. Higher CO results in loss of power in engine. The CO increased primarily due to incomplete combustion resulting from antioxidant addition. Lower CO emission of MSME when compared to that of diesel is attributed to the combined effect of higher cetane number and oxygen content. A higher cetane number exhibits a shorter ignition delay and allows a longer residing of the combustion product inside the combustion chamber which results in oxidation of CO. Addition of LAA have slightly increased the CO emission characteristics of MSME.

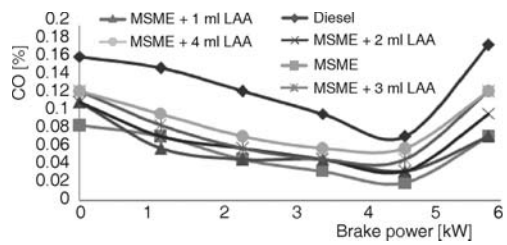

Figure 7. Variation of CO with brake power

Hydrocarbon

Figure 8 shows the HC emission for different test fuels. Unburned HC come under different forms such as vapour, drops of fuel or products of fuel after thermal degradation. The HC emissions contribute to the formation of smog and may include photo-chemically reactive species as well as carcinogens. The HC emission reduces with the increase in load for the fuel due to the increased combustion chamber temperature which supports the better oxidation of unburned HC. The MSME has a substantial reduction in HC emission due to the higher oxygen content of the MSME which supports the oxidation of fuel in the combustion chamber. It is clear from the figure that the addition of LAA with MSME led to increase in HC emission of MSME with its proportion at all loads, which is attributed to the reduction in the oxidative free-radical formation. However the HC emission is still lower than the diesel.

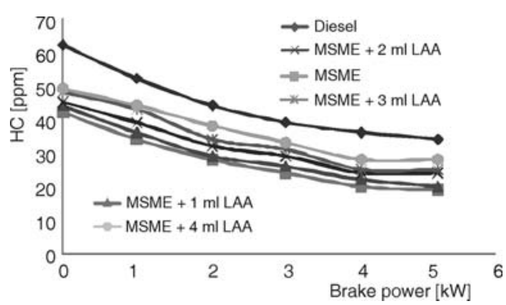

Figure 8. Variation of HC with brake power

Conclusions

From the experimental investigations the following conclusions were arrived.

- Biodiesel from mango seed can be used as alternate fuel in a Diesel engine.
- Lower calorific value of MSME resulted in reduction in BTE and increase in SFC.
- The CO, HC, and smoke emission of MSME is significantly lower than the diesel at all load due to the presence of oxygen in the MSME and higher cetane number.
- The HC, CO, and smoke emission of MSME increases with the increase in LAA proportion in MSME but it is lower than the diesel.
- Addition LAA has a considerable effect in reducing the NO_x emission from the engine, by scavenging free radicals. NO_x emission reduced by addition LAA with MSME due the reduction in formation of free radicals. The emission characteristics of 4 ml LAA is almost similar to that of the diesel fuel. Addition of more than 4 ml of additive does not have any significant effect on the NO_x emission characteristics.

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